PENETRATION OF DAYLIGHT INTO THE WATERS OF THE GENEVAN LAKE AND INTO THE MEDITERRANEAN.

A SPECIAL COMMISSION appointed by the Society of Physics and Natural History to study the colour and transparency of the waters of the Lake of Geneva have investigated the extreme limit reached by daylight in the depths of the lake.

Many naturalists have investigated this interesting subject. Amongst others, Prof. F. A. Forel, of Morges, spent much time in investigating the Lake of Geneva. Using paper specially prepared for photography, M. Forel arrived at very interesting conclusions as to the greater transparency of the water in winter than in summer. But the paper was not sufficiently sensitive to permit of the determination of the exact limit to which the light of day extends in the depths of the lake.

Another Swiss naturalist, M. Asper, engaged in the same research, and examined several lakes, especially Zürich and Wallenstadt, for the extreme limit of the penetration of daylight. He made use of dried photographic plates of gelatine-bromide of silver. Proceeding in the same way as M. Forel, he put his plates in in the night, and took them out the following night, thus neglecting the action exercised on the sensitive plate by the light which still exists in the sky, even on a moonless night, at the moment of putting in and taking out.

This action, however, should not be neglected, and its neglect is the source of considerable error. The researches of M. Asper were carried out in lakes where the waters are less pure, and therefore less transparent, than those of the Genevan lake; they are therefore special to the lakes which he studied, and do not bear upon our lake. M. Asper, having found light at the lowest depth to which he immersed his plates (140 metres), could not answer the question as to the limit of penetration.

1. *On the Extreme Limit of the Penetration of Daylight into the Waters of the Lake of Geneva.*

The recent work, like that of M. Asper, consisted in exposing photographic plates at various depths in the deepest parts of the lake. The rapid gelatine-bromide plates of Munkhoven were used. A special apparatus, warding off from the sensitive plate all light other than that which really penetrated at the depth to which it was plunged under the water, was added. This apparatus, constructed by the Genevan Society for the Construction of Instruments in Physics, consists of a box of rectangular shape, of brass, 40 centimetres in length and 20 in breadth, containing in the middle a sensitive plate fixed by wedges. This frame is closed in the upper part by two brass shutters, gliding into grooves with double borders, separated from each other by means of a strong spring contained in the bottom of the box, so as to leave the plate entirely uncovered. At the bottom of the frame a strong shaft is fixed in the form of a ⊥, which bears the axes of rotation of two levers coupled in the form of scissors. Each of the levers ends in the upper part in a fork whose teeth pass from one side of the frame to the other, and lean against two branches which each of the shutters bears. Under the action of the inner spring the shutters separate, and with them the two arms of the lever. A weight is suspended at the opposite extremities of the two levers, and acts on them like the pressure of the fingers closing a pair of scissors; the two forks approach one another, and with them the two shutters, which then cover the plate entirely and defend it from any luminous action from without. A hook fixed to one of the shutters, turns on the apparatus when it is shut, and hangs in the groove of the other shutter, preventing them thus from separating during the transport from the dark chamber to the site of the experiment; it is raised only at the moment that the apparatus is attached to the sounding-line and worked on by the weight; as soon as the sounding-weight reaches the bottom, it opens under the action of the antagonistic spring; it closes again immediately it is withdrawn, and the weight leaving the bottom recommences to act. The depth having been ascertained by previous sounding, the length of the cord is regulated by which the weight is suspended to the apparatus, 100, 200, 300 metres for instance, at the distance desired from the surface of the water. After exposure for a certain time, the apparatus is withdrawn and carried into the dark room established on the ship in order to change the plates, and, if necessary, to develop them immediately.

The duration of the exposure has been about ten minutes. The development has been effected by means of oxalate of iron, with which the workers acted on each plate for ten minutes. The plates were all covered by the same emulsion.

Experiments have been made near Evian, where the lake presents a pretty wide plain at 310 metres depth. M. Marcet was twice kind enough to put his steam yacht, the *Heron*, at the disposal of the Commission; and Prof. Forel, of Morges, was kind enough, not only to lend his sounding-line, but to aid by his advice and his experience.

August 16, 1884, weather clear, sun bright: (*a*) at 237 metres, two plates, one at 12.30, the other at 1.7; (*b*) at 113 metres, a plate at 2.30; (*c*) at 300 metres a plate at 2.44.

September 23, 1884, dull, but very clear weather, thin, pretty luminous clouds, light wind varying from east to north, we exposed: (*d*) at 147 metres, a plate at 1 o'clock in the afternoon; (*e*) at 170 metres, a plate at 2.26; (*f*) at 113 metres, a plate at 3.3; (*g*) at 90·50 metres, a plate at 3.34.

For the sake of comparison, M. Fol had, on August 15, at 10 p.m., exposed on a clear but moonless night: (*h*) a plate in the open air for ten minutes; (*i*) a plate in the open air for five minutes.

It was found that plate *c* (300 metres in depth) had received no luminous impression whatever. It was the same with plate *a* (237 metres). Plate *e*, at 170 metres, was lightly veiled, almost like plate *i*, exposed for five minutes during the night. Plate *d*, at 147 metres, had been vividly impressed, more than plate *h*, exposed in the night for ten minutes. Of the two plates at 113 metres, the plate *f* of the second day is much darkened, whilst plate *b* of the first day is no more impressed than plate *d* of the second day. Plate *g*, exposed at 90 metres, is so impressed that characters which had been traced on the back are only incompletely reserved on the dark background of the developed layer.

On comparing the results obtained in the two days of experiment one is struck by the fact that the photographic effect was much stronger on September 28 than on August 16.

From these two attempts the conclusions are drawn:—

(1) That daylight penetrates into the waters of the Lake of Geneva in September at 170 metres depth, and probably a little beyond that; that at this depth the amount of light in the day is almost similar to that perceived in a clear moonless night.

(2) That at 120 metres the action of transmitted light is still very strong.

(3) That in September, in dull weather, light penetrates in greater abundance and more deeply into the water than in August in fine weather.

Later experiments will show us whether this difference is to be attributed to the greater transparency of water in autumn and winter, which the experiments of M. Forel ascertained beyond doubt, or if the light diffused by the clouds penetrates more deeply than the more or less oblique rays of the sun.

Before these experiments M. Asper had exposed plates of gelatine-bromide in the Lake of Zürich at depths between 40 and 90 metres, in the Lake of Wallenstadt from 90 to 140, and he obtained an effect from all. He put them in in the night, left them exposed a whole day, and took them out the following night. But, as the exposures of plates *h* and *i* have shown, the darkest night is still light for a plate of rapid gelatine-bromide.

2. *On the Extreme Limit of the Penetration of Daylight into the Waters of the Mediterranean Sea.*

After being assured by the experiments in the Genevan lake that their apparatus worked well, the Commission desired to make similar experiments in the sea, in which the greater transparency of the water would lead one to suppose that the extreme limit of the luminous rays would be at a still lower level.

No satisfactory experiments had yet been made in regard to this, for the experiments of the *Porcupine* were not carried out, M. Siemens's apparatus refusing to work.

Owing to the kindly mediation of Dr. J. Barrois, Director of the Zoological Station of Villefranche-sur-Mer, the *Albatros* was put at the disposal of the Commission for several days in the spring of 1885.

The method of procedure was the same as for the experiments in the lake, only that it was important to preserve the sensitive plate against the chemical action of the salt water by adding a thick layer of varnish to the bitumen. The luminous impression was made by the back of the plate and through the thickness of the glass. Repeated washings with essence of turpentine and alcohol sufficed to remove the varnish before proceeding to the development. As before, oxalate of iron was used.

The experiments took place on March 25 and 26, 1885, and were favoured by calm and fine weather. The depths wanted were found near Cape Ferrat, from 400 to 600 metres.

A. From 10.30 to 10.40, plate exposed at the depth of 200 metres to start with.

B. From 12.45 to 12.50, at a depth of 280 metres.

C. From 11.30 to 11.40, at a depth of 345 to 350 metres.

D. From 10.55 to 11.5, at a depth of 360 metres.

E. From 10.15 to 10.25, at a depth of 380 metres. This experiment took place under exceptionally favourable circumstances; there was no breeze, the ship remained perfectly stationary, and the line perfectly vertical.

F. From 1.20 to 1.30, cloudy but pretty light, at a depth of 405 to 420 metres. All these plates except F were exposed during bright sunshine.

Plates A and B were found to be very much impressed. On the plates C, D, and E the strength of the impression diminishes very regularly with the increase of depth. On plate E the strength of the impression is notably inferior to that of an exposure of the same duration in the air, on a clear moonless night. It may be compared to that of a shorter exposure, five minutes only, in the latter conditions. Plate F does not bear the least trace of any impression whatever. It is no doubt to be regretted that this last experiment did not take place, like the others, in clear weather. But the degree of the impression of plate E, of 380 metres, is already so weak that it may be pretty safely concluded that the extreme limit could not be more than 20 metres lower. On the other hand, the experiments in the Lake of Geneva have shown that the dispersion of the sunlight by a light layer of clouds does not bring about a notable diminution in the depth which it may attain in the water.

It is concluded, then, from these experiments, that in the month of March, in the middle of the day, with a bright sun, the last rays of daylight stop at 400 metres from the surface in the Mediterranean.

3. *Effects of the Seasons on the Limit of Penetration of Daylight in the Waters of the Lake of Geneva.*

The experiments of M. Forel, mentioned above, showed that photographic paper dipped in the lake is blackened in winter to a depth of 100 metres, whilst in summer it is not blackened beyond 45 metres. It is interesting to know whether this variation of transparency with the season belongs only to superficial layers, or if the same law holds good also at lower levels.

March 18, 1885, the Commission went into the middle of the lake on the *Sachem*, steam yacht of M. E. Reverdin, which its owner put at their disposal. As in former experiments on the lake, M. Forel was present. The weather was pretty clear; a light layer of clouds dispersed the light without arresting completely the direct rays of the sun. The following plates were exposed: (*k*) from 9.20 to 9.30, at 158 metres; (*l*) from 10.0 to 10.10, at 192 metres; (*m*) from 10.30 to 10.40, at 235 metres; (*n*) from 10.10 to 11.20, at 240 to 245 metres; (*o*) from 11.48 to 12.23, at 280 to 300 metres.

The duration of exposure was uniformly ten minutes for all, save the last, which remained uncovered, at 280 metres, for 35 minutes. In spite of that, not the least trace of impression was visible either on this plate or on plates *m* and *n*. The plate *l* was very faintly impressed, almost like plate E, of 380 metres in the sea. Plate *k*, at 158 metres, is of nearly the same force as C.

These experiments show that the extreme limit of the action of daylight in the lake in winter is a little beyond 200 metres.

A comparison between this series of experiments and the preceding shows that the light only descends 20 or 30 metres lower in March than in September; the difference is perhaps a little more considerable in the month of August. The layers of water situated below 100 metres escape the law of variation of transparency established by M. Forel for the more superficial layers; the variations of temperature accompanying the seasons, on the effect of which M. Forel bases his theory, not being sensibly felt beyond a certain depth.

Compared to the series of plates exposed in the lake, the series brought from the Mediterranean is striking by its slower and more regular gradation. This gives rise to the idea that whilst in the lake the light is promptly intercepted by deep layers more or less troubled, in the Mediterranean the absorption of the pure water would be the principal if not the only factor in the arrest of the luminous rays.

4. *On the Penetration of Light in the Depth of the Sea at Different Times in the Day.*

The preceding experiments led to very exact determinations of the extreme limit of the penetration of daylight in the waters of the Lake of Geneva and in those of the Mediterranean.

The following year, pursuing the same kind of experiments, the relations which exist between the depth to which light reaches in the water and the inclination of the sun or the variations in the amount of light were investigated.

The Report continues:—

"As we no longer sought a single limit, but a series of limits at fixed times during the day, we required a series of plates exposed at the same instant at different depths and capable of comparison with one another. Instead of a single large apparatus, like that which we had been using, we used twelve small ones, constructed on the same principle, which we placed at regular intervals of 20 metres along the cord. These apparatus were also furnished by the Genevan Society for the Construction of Instruments in Physics. They consist of a little rectangular frame of brass, in which glides in double grooves the drawer containing the sensitive plate, and which an interior spring tends always to open. The frame is fixed by two rings of brass, which at their upper part allow the axis of rotation of a lever to pass. The apparatus is suspended to the sounding-cord by an arm of this bent lever, whilst the lower arm acts on a spring fixed to the drawer. The lower part of the cord is attached to a cross-bar which unites the bottom of the two rings. When the cord is stretched under the action of the sounding-weight, the upper arm of the lever falls into the prolongation of the cord, in a vertical position, and the lower arm keeps the drawer close. When the action of the sounding-weight ceases, the drawer opens under the action of the antagonistic spring. The process is the same as in the large apparatus, but in a slightly different form, permitting a much smaller and lighter order, which is more suitable to the superposition in series. To avoid the lower apparatus interfering by their additional weight with the opening of the higher ones, when the action of the sounding-weight ceases, each apparatus and the corresponding cord were exactly counterbalanced by a floater of glass in the form of a vial, inclosed in a net and attached to the cord immediately below the apparatus which is wished to be free. Under these conditions the apparatus all open simultaneously, immediately that the sounding-weight touches the bottom, and also close all together at the moment when the cord is drawn up and the sounding-weight begins again to act on them. The simultaneous exposure of several plates at various depths is thus obtained, and it is possible to follow the decreasing action of the light with the depth in one and the same experiment, all circumstances being equal."

The sensitive plates used in these experiments were those of extra rapid gelatine-bromide of M. Lumière, at Lyons. They were protected by a varnish from the action of the sea-water. The duration of the exposure and that of the development were both ten minutes, as in the preceding experiments.

They were carried on in a locality presenting a depth of about 500 metres, so that the purity of the water and the limit of the light were not influenced by the nearness to the bottom. The place chosen was 1300 to 1500 metres from the Cape of Mont Boron, separating the strand of Villefranche from the Gulf of Nice.

Amongst the series of plates obtained the following succeeded well and are particularly instructive.

Series A.—Between 1.15 and 1.25, April 7, 1886, the sun being about 60° above the horizon. The sky was very clear and the sun brilliant; a moderate breeze from the east made little waves.

Plate 1. Exposed at 430 metres: no trace of luminous impression.

Plate 2. Exposed at 390 to 393 metres: a very faint trace, but yet a clear one.

Plate 3. Exposed at 350 metres: a still faint impression.

Plate 4. Exposed at 310 metres: a strong impression.

Plate 5. Exposed at 270 metres: a very strong impression.

Plate 6. Exposed at 230 metres: completely blackened, as were the following.

The limit of light is, then, very exactly towards 400 metres in April, in the middle of the day, in fine weather. This is as complete a confirmation as possible of the conclusion arrived at in the preceding experiments.

Series B.—Between 8.20 and 8.30, April 5, 1886. Sky veiled by a uniform layer of white clouds thick enough for the sun to project no shadow. Moderate breeze from the east.

Plates 1, of 450 metres, and 2, of 415, have no impression.

Plate 3, of 350 metres, presents a very slight impression, a little less strong than that of plate 3 (390 metres) of Series A.

Plate 4, of 315, is of the same force as plate 3 of Series A.

Plate 5, failed by accident.

Plate 6, of 245, and the following, are completely blackened.

Series C.—Between 6.5 and 6.15, April 8. The setting sun was hidden by a bank of black clouds. The rest of the sky was pretty clear, with some little cirro-strati with a faint white light. The light was altogether faint, and like that which is generally found when the sun has just set. The surface of the sea was little agitated, with a slight breeze from the west.

Plates 1, of 400 metres, 2, of 340 metres, and 3, of 300 metres, have no trace of impression.

Plate 4, of 260 metres, is of almost the same force as plate 3 of Series A.

Plate 5, of 220 metres, similar to plate 4 of Series A.

Plate 6, of 180 metres, like plate 5 of Series A.

Plate 7 and the following, completely blackened.

The limit in this last series may be placed with all probability at 290 to 295 metres from the surface.

We see from these experiments that the layers situated at 300 metres are lighted every day, not for a very short time, but all the time that the sun is above the horizon; at 350 metres the light penetrates at least during eight hours daily.

According to the tables that M. Holatschek has drawn up for the latitude of Vienna, especially after the photochemical experiments of MM. Bunsen and Roscoe, the actinic intensity of the light of the blue sky would be on April 21, 33 at 8.30 in the morning; 38·07, at noon; and 14·18 at 6 p.m.; that of the sky and the sun at once would be on an average, in April, 75 at 8.30 a.m., 133 at noon, and 15 at 6 p.m.

According to these figures, the depth that the actinic rays attain in the sea after the setting of the sun is very remarkable. The Commission wait, however, to have more numerous experimental proofs to try to calculate a formula of absorption of which they have to determine the constant for sea-water.

5. *New Experiments on the Effect of the Seasons on the Limit of Penetration of Daylight in the Lake of Geneva.*

The results of these, which require to be confirmed under better conditions, seem to indicate that the difference of transparency between the waters of the lake in winter and in summer is greater than one would have thought. On the other hand, the want of agreement with the experiments of Series 3 leads one to think that the distribution in extent and depth of the layers of troubled water brought by the affluents of the lake is subject to variations difficult to foresee and to appreciate.

The Report concludes by referring to certain improvements in the apparatus.

THE REPORT OF THE KRAKATÃO COMMITTEE OF THE ROYAL SOCIETY.

PART IV. of this Report, on the optical phenomena, by the Hon. F. A. Rollo Russell and Mr. E. Douglas Archibald, comprises 311 pages of letterpress, or the major portion of the work. Owing to the enormous mass of material which went on accumulating for nearly four years from the date of the eruption, as well as the complexity surrounding the optical phenomena, which in some cases were entirely novel, and in others differed both in quality as well as intensity from their normal analogues, it was plainly a work of some considerable difficulty to decide how best to arrange and discuss the data, as well as to avoid arriving at hasty conclusions from the first indications of appearances which continued in part right up to the beginning of 1887. When the wonderful sunsets appeared in this country, the idea of their being connected with the eruption of Krakatão was first suggested and traced out with remarkable clearness by Mr. J. Norman Lockyer, F.R.S., in his article in the *Times* (December 8, 1883).

From the results of certain experiments by himself, he